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THE BIOGRAPHY OF HELMHOLTZ.

Hermann von Helmholtz. By Leo Koenigsberger. In three volumes. Vol. i. Pp xi + 375. Price 8 marks. Vol. ii. Pp. xiv + 383. Price 10 marks. Vol. iii. Pp. xi + 142. Price 3 marks. (Brunswick: Vieweg, 1903.)

I.

Education and Physiological Work.

THE third and last volume of Koenigsberger's biography of the great natural philosopher has now appeared. The whole work is worthy of its subject; the author made it his aim, as he tells us in his preface, to set forth Helmholtz's manifold and various achievements as a discoverer in such a way as to render them intelligible to all scientific readers. Helmholtz is best known by his discoveries in experimental physics, but during the first half dozen years after the completion of his professional education, the business of his life was that of an army surgeon. It was as an army surgeon that he published, between 1842 and 1848, those remarkable researches on fermentation, on the nature of muscular contraction, and on the production of heat therein, the results of which served as the foundation for the building up of a new science of physiology. Even the treatise on the "Erhaltung der Kraft," or, as we now call it, the conservation of energy, although mainly physical, exercised its chief influence on physiologists. In natural philosophy the principle set forth in it had been already recognised, but had not as yet been presented to the physiological student as a fundamental doctrine, or successfully applied to the phenomena of life.

The biography of a man of great intellectual pre-eminence fulfils its highest purpose by enabling us to form a just estimate of the antecedent and surrounding influences which made him what he was. Herr Koenigsberger has treated his subject in such a way as to afford the information that the scientific reader seeks. How can we account for the production of a man of such extraordinary endowments? Did Helmholtz owe his intellectual superiority to his innate qualities, to his parentage, to his education, and if to the latter, was it due to his teachers or to his contemporaries? Koenigsberger's indications lead us to believe that in each of these respects his life was influenced by circumstances exceptionally favourable to his intellectual development.

Nationally, Helmholtz was of mixed descent. It may be assumed that his father was German, but his mother was half English, half French. Her maiden name, Caroline Penn, was derived from the great Quaker of the seventeenth century, who himself was the son of an almost equally distinguished English admiral. On the female side she was of Huguenot descent.

There can, I think, be no doubt that the moral and intellectual atmosphere of the Helmholtz home was excellent. The little that we are told of his mother indicates that she was a woman of great simplicity of character, but at the same time of unusual intelligence, who devoted herself heart and soul to promoting the happiness of her husband and children. His father was at the head of the Gymnasium at Potsdam, a position which he had attained after many years of arduous struggle with adverse circumstances. He appears to have been an enthusiastic teacher, who made it his aim rather to evoke in his pupils a love for the classical writers than to drill them in grammatical niceties.

Of Helmholtz's childhood we are told that, although his mother recognised in her firstborn "Geist und Verstand," there was no other indication of infantile precocity. At nine he entered the lowest class in the Gymnasium, but in a year was half-way up the school. His progress, however, was retarded by the difficulty which he had in learning anything by heart. During his first three years he went through the regular classical work of the school, but he appears even at this early age (ten to thirteen) to have done much extra work under his father's direction, who encouraged him to extend his studies beyond the limits of the school course. At thirteen he began the study of mathematics under a teacher who appears to have had as great a faculty for exciting enthusiasm for work in natural science as the father had in literature. Helmholtz continued his classical work, but became more and more engrossed by his studies in mathematics and physics, the subjects which, he says in his "*Abiturientenvita,*" "omnium disciplinarum maxime a pueritiâ me delectavit," so much so that when the rest were engaged in construing, he "beguiled the tedious hour" by working problems "under the table." By the time he was fifteen, he had already made up his mind to devote his life to natural science.

His father's means were so limited that the only way in which this desire could be gratified was by taking the study of medicine "into the bargain." He therefore at sixteen, while still a "gymnasiast," became a pupil in the Friedrich-Wilhelm-Institut at Berlin (the Pépinière) for the training of army medical officers. Two years later (at eighteen) he passed the *Abiturienten-Examen*, showing "comprehensive and thorough knowledge in the elements of mathematics and physics." He obtained at the same time distinction in classics, exhibited a good knowledge of French, English, and Italian, and had made sufficient progress in Hebrew to be able to offer that language as an extra subject. It was thus that he was equipped for the business of his life. That he possessed extraordinary natural endowments cannot be questioned, but it is no less certain that he owed the early maturity of his intellect and his exceptional heuristic power to an almost perfect education.

Whatever be the place among contemporary physicists to which his achievements entitled him, it can scarcely be questioned that as a physiologist he was *primus inter pares*. He was the first to understand what is meant by the well-known definition of life as "organism in action," and thus to distinguish clearly between that branch of the science of life which deals with organism and that which relates to the chemical and physical processes by which its action manifests itself. In the former Helmholtz did not much interest himself, and consequently was not, in the modern sense of the word, a biologist. His aim was not to inquire *why* the animal (or plant) body assumes in its development the characters which it presents to the naturalist, but rather to discover in what processes vital action consists, and to prove that these processes are identical with those of inorganic nature, and can only be investigated by the methods of exact science. But Helmholtz was far from supposing that these methods could be applied either to organism and its evolution or to the study of mental processes, and expressed his distrust of the efforts made by others in this direction, with perhaps too great contempt.

Helmholtz's professional education began when he left school in 1838, and occupied four years. It is noteworthy that, notwithstanding the almost incredible amount of work which was imposed on the students of the Pépinière by a curriculum which not only included anatomy, physiology, pathology, and practice, and the sciences then regarded as ancillary to medicine, but also logic and metaphysics, ancient history, and modern languages, Helmholtz still found leisure for other pursuits. He was not only able to obtain that mastery of music of which he was afterwards to make so splendid a use, but also to pursue without any assistance, except such as he derived from books, the higher branches of mathematics, in the elements of which his schoolmaster (Meyer) had so thoroughly grounded him.

It need scarcely be said that during this period of ceaseless exertion he became intimate with the greatest of his teachers, J. Müller, and thus, as he said himself, had another opportunity of observing "wie die Gedanke selbstständiger Köpfe sich bewegen." This intimacy was, no doubt, of great value to him, but there is no sufficient ground for the conjecture which has often been made that it was from Müller that he derived his inspiration. The two men were cast in such different moulds that this was scarcely possible. The subject which Helmholtz selected for his Latin graduation essay ("The Structure of the Nervous System in Invertebrates") was no doubt suggested by Müller, but Helmholtz was no sooner himself free ("selbstständig") than he followed his own bent. It seems probable that, even when he was working assiduously with Müller as a biologist, he anticipated the direction in which his future studies would lead him, and was already aware that physics and chemistry, not biology, would afford him effectual methods of research.

Helmholtz graduated in 1842, and soon entered on his duties as a military surgeon. These happily gave him sufficient leisure for his scientific work. His first research, of which the results were published in Wagner's "Handwörterbuch," was on the relation between the work done and the heat produced in muscular contraction. It was important as setting forth one of the fundamental facts on which the new science was to be built, and as preliminary to the treatise on the "Erhaltung der Kraft," which appeared two years later. Of the genesis of this work Koenigsberger gives an interesting account. The introduction to it was written in 1846, the very same year in which, at the age of twenty-five, he passed his final *Staatsexamen* as a practitioner of medicine and surgery, his examiners possibly little guessing whom they had before them. The manuscript of the introduction was put for friendly criticism into the hands of du Bois-Reymond, who, however, would make no change in it, regarding it as an "historisches Document für alle Zeiten." It was forthwith communicated to the recently founded Physical Society of Berlin, the young and active members of which thus became acquainted with the law of the conservation of energy long before it had been discussed by academicians. By the Physical Society it was received with enthusiasm, but when offered to Poggendorff for publication in the *Annalen*, he declined it as being too theoretical, promising, however, to accept it as soon as experimental proofs were forthcoming.

The four years during which Helmholtz was charged with regimental duties were so productive that, in 1849, when a vacancy occurred in the University of Koenigsberg, he was selected by the Minister of Public Instruction among the four whom J. Müller had recommended, namely, Ludwig, Helmholtz, du Bois-Reymond, and Brücke, as the men most capable of advancing science in the "physico-physiological direction." All of these men, whose claims Müller estimated to be equal, were young, but Ludwig was the senior, and would have received the appointment had not a suspicion of radicalism, wholly unfounded, attached to him. So Helmholtz became, at twenty-eight, professor of physiology with the magnificent salary of 120*l.* a year!

Helmholtz's removal to Koenigsberg was followed by a period of astonishing fruitfulness in discovery. The first new subject to which he directed his attention was that of the measurement for physiological purposes of extremely short intervals of time, and the application of these methods to the determination of the rate of transmission in nerve. This he accomplished with such completeness and exactitude that his results can, even now, be accepted without question. In the meantime he continued those studies in physiological optics which led to the discovery of the ophthalmoscope. This, as well as the subsequent discovery of the mechanism of accommodation of the eye for distance, was communicated to the Physical Society. Then followed an investigation of the time-relations of induction currents, a research of great importance in the technique of experimental physiology. His first researches on colour-vision were published in Poggendorff's *Annalen* in 1852, in which journal also appeared, about the same time, another research of great value in its bearing on electro-physiological questions—an investigation of the "distribution of currents in bodily conductors."[1] It was towards the end of the Koenigsberg time that Helmholtz made his first visit to England. In his letters home he refers with evident pleasure to his intercourse with English physicists, and especially to the impression made upon him by Faraday's "herzgewinnendes Wesen," and observed with great interest how "old bits of wood and wire" sufficed him for the making of the greatest discoveries. He no less highly appreciated the friendly welcome given him by the Astronomer Royal, Airy, and the opportunity of exploring Greenwich Observatory, and of seeing in operation the first successful method of recording photographically the readings of magnetic and meteorological instruments. With Thomson, Helmholtz did not come into personal relation until August, 1855, when they met at Kreuznach. Helmholtz describes (in a letter to his wife) his astonishment when a man whom he knew as one of the first of living mathematical physicists appeared to him as a "Jüngling von ganz mädchenhaften Aussehen," but possessed of a degree of acuteness, clearness, and versatility which he had never before met with. It can well be imagined how these two young discoverers must have enjoyed and profited by the exchange of thought on fundamental questions which each of them had done so much to elucidate.

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[1] See vol. i. p. 177.

The same year Helmholtz accepted the chair of anatomy and physiology at Bonn, his motive for doing so being that his wife, whose health was precarious, might have the advantage of a milder climate. At that time the two subjects were still united, so that Helmholtz was obliged to resume the teaching of descriptive anatomy. This drawback was, however, of short duration, for two years later he was invited to Heidelberg, where the conditions were much more favourable. Notwithstanding the onerous nature of Helmholtz's professional engagements, the fifteen years of his residence at Bonn and Heidelberg were almost as productive as those which had preceded them. It was at Bonn that he sent to the press the first part of his famous treatise on physiological optics, which was not completed until 1895, and there also that he carried out many of the researches on musical sounds which were embodied in his treatise on "Sensations of Tone." At Bonn, too, he published his first mathematical paper "On the Movement of Fluids" (1858), which led on to his experimental researches at Heidelberg in 1860. During the whole period it appears that he published some forty-six papers of importance, of which thirty-seven, including those on optics and acoustics, were on physiological subjects, the remainder being physico-mathematical.

After his appointment to the chair of physics at Berlin, his only physiological publication was the essay entitled "Thought in Medicine," in which he illustrated in the most striking way the application of the scientific method to pathological questions. (The chapters of Koenigsberger's work which relate to Helmholtz as a mathematician will be treated by abler hands. Many readers who may not have leisure to look into this admirable biography would have been glad had it been possible to give some account of Helmholtz's views as to the limits of a scientific inquiry and the relation between the experimental sciences and philosophy. Want of space forbids this.)

In Koenigsberger's book the reader will find ample material for the decision of the question which presented itself at the outset, that of the conditions which led to the development of so splendid a character. To the present writer it seems evident that Helmholtz's personal qualities—his sagacity, modesty, truthfulness, and astonishing power of work—could be in great measure attributed to home and school influences, and that his success as an investigator was due in part to his having entered on his career as a physiologist at a time when the progress of the exact sciences had rendered their methods applicable to the investigation of vital phenomena, and in part to his singular good fortune in having as his fellow-students such men as du Bois-Reymond, Ludwig, and Brücke, each of whom was as enthusiastic as himself, and scarcely inferior to him in intellectual endowments.

J. BURDON-SANDERSON.

II.

PHYSICO-MATHEMATICAL RESEARCHES.

Herr Koenigsberger gives us an account of Helmholtz which is extremely interesting, and not unworthy of the investigator of whom he writes. Though he paints for us a fascinating picture of Helmholtz as a man, it is with work as a great physiologist and physicist that he chiefly deals.

A review of that part of the biography which deals with the education and physiological work of Helmholtz precedes this notice, which is confined to a brief account of that part of the book treating of his physico-mathematical writings. Helmholtz's first mathematical paper was "On the Integrals of Hydrodynamical Equations which correspond to Vortex Movements," and was published in 1858, during his short stay in Bonn as professor of anatomy and physiology. In the following year, after his migration to Heidelberg as professor of physiology, appeared his paper "On the Motion of Air in Pipes with Open Ends." These two papers contain some of his most brilliant mathematical deductions, and are characterised by their freedom from the artificial or inaccurate assumptions of his predecessors. Further work in this direction was for the time prevented by family troubles. In June, 1859, his father died of a sudden stroke, and Helmholtz, worn out with sorrow at his loss, with anxiety for his wife, and with his own bad health, was obliged to turn to work requiring less concentration of thought. At the end of the year his wife died. For some time his health remained in an unsatisfactory state, and he was subject to headache and fainting fits. However, he forced himself to work, "which alone could give him power to hold out," and continued his hydrodynamical investigations, publishing in April, 1860, his paper "On the Friction of Viscous Fluids." His experimental researches on sound then led him to study the mathematical theory of violin strings and reed organ pipes.

Continuing his researches in acoustics and optics, he was led by the consideration of the wave motion near the end of an open cylindrical tube to investigate the distribution of electricity near the circular intersection of two surfaces. However, in this, the first of his many papers on mathematical electricity, he had been anticipated by Thomson. He then for some years confined himself mainly to physiological work, and it was not until 1868 that he was again led by his acoustical researches to the study of hydrodynamics. Shortly after this his physiological work induced him to again attack electrical problems. From the study of electrical oscillations he proceeded to a discussion of the most general form of expression for the potential of single "Stromelemente," and of the differential equations which determine the motion of electricity. In this first treatise on electrodynamics, Helmholtz aimed at giving a clear summary of all results previously obtained.

In 1871 Helmholtz was appointed to the professorship of physics at Berlin in succession to Magnus, which post he held until 1888. From this time onward he confined himself almost entirely to physics, and did very little more physiological work. In the following year, after the marriage of his daughter Käthe, and a visit to Scotland (where he met Tait, Andrews, Huxley, Brown, Sylvester, &c., and found golf less easy to master than science), he published further papers "On the Theories of Electrodynamics." In these he replied effectively to the criticisms of Bertrand, Weber, &c., and, basing his researches on Neumann's potential law, he investigated the various theories that had been put forward, showing that Faraday's assumption of dielectric polarity was the only theory consistent with observed properties of open and closed circuits. For a short time after this he applied his versatile genius to the problem of artificial flight and guidable balloons, made valuable contributions to the theory of the microscope and anomalous dispersion, and turned his attention to the origin of thunderstorms. He then returned for some years to his researches in electricity, and applied Faraday's theories to electrochemistry, producing papers on electric currents in fluids and "elektrische Grenzschichten."

In 1878 commenced his lifelong friendship with Hertz, whose investigations led Helmholtz back to his electrodynamical researches, and to the discussion of the electromagnetic theory of light. In 1881 he again visited England, where he delivered his famous "Faraday lecture" (one of the best lectures he ever gave), which was received with the greatest enthusiasm. The delivery of this discourse led him to further investigations in electrochemistry, and in "The Thermodynamics of Chemical Processes," published in 1883, he discusses the relations of chemical combination, heat, and electrical potential, distinguishing between the "free" energy of a system which can be entirely converted into work and the "bound" energy which cannot be so converted. After journeys to Rome and England, he undertook a masterly development of the principle of least action, a principle which he considered as probably being the controlling law of all reversible processes of nature.

During the last year of his professorship at Berlin Helmholtz returned to his work on electrical and thermodynamical chemistry, and to the development of the "principle of the decrease of free energy in chemical processes." In 1888 he was appointed president of the newly-founded Physico-technical Institute, a position in which he had comparative freedom from routine work, and so was enabled still more thoroughly to devote himself to those investigations for which he was so peculiarly fitted. His first great work in his new position was the adaptation of the equations of hydrodynamics to the case of layers of gases of varying density, and the application of his results to meteorological phenomena. The remaining four years of his life were devoted to more work on the mathematical theory of electricity. The most important papers were those on the application of the principle of least action to Maxwell's electrodynamical equations, on the electromagnetic theory of colour dispersion, and on Maxwell's theory of the motion of the ether. He died, after two months' illness, in 1894.

HAROLD HILTON.

THE EARTH-HISTORY OF CENTRAL EUROPE.

Central Europe. By Prof. Joseph Partsch, Ph.D. Pp. xiv+358; with maps and diagrams. (London: William Heinemann, 1903.)

PROF. PARTSCH'S geography of Central Europe forms a volume of the series "Regions of the World," edited by Mr. H. J. Mackinder. Written in German, it has been well translated by Miss Clementina Black, and has also undergone a little condensation, probably to its advantage. On the east and part of the south, the region has fairly definite physical boundaries, in other directions they are more often political; but practically Central Europe includes the two great empires of Germany and Austro-Hungary, with Switzerland, Belgium and the Netherlands on the one hand, Montenegro, Servia, Bulgaria and Roumania on the other. But in the main there is a general correspondence between the political and the physical boundaries of the region, for Central Europe, geographically speaking, as Prof. Partsch remarks, is a three-fold belt of Alps, of inferior chains and of northern lowlands, and wherever one of these elements dies out Central Europe comes to an end. This is the best natural definition, though we should have preferred the term central highlands to "inferior chains," and a little clearer insistence on the fact that the great mountain chains of Europe—the Alps, Pyrenees and Carpathians—are comparatively modern physical upstarts, the highlands being much more ancient regions, which, like some old families, have come down in the world. Still, Prof. Partsch makes it clear, in a chapter which certainly would not stand any more compression, that the development of Central Europe was a long and complicated story. His remarks on traces in the Alps of valley systems older than the present, illustrated by some rough but sufficient diagrams after Prof. Heim, will be very suggestive to students, though full justice can hardly be done to the subject within the limits of this volume, because mountain making in this region was a complicated and intricate process, involving many speculative elements. He does well also in calling attention to the aggressive habit of some rivers; the more active one cutting back through the old water parting and capturing the other's tributaries. The Maloya Pass affords, of course, a typical example of